



## REPORT TO THE OFFICE OF NAVAL RESEARCH

MULTICOMPONENT AND MULTILAYERED THIN FILMS FOR ADVANCED  
MICROTECHNOLOGIES: TECHNIQUES, FUNDAMENTALS, AND DEVICES

21th September - 2nd October, 1992, Bad Windsheim, Germany

**DIRECTOR:** Dr. Orlando Auciello, MCNC, Center for Microelectronics,  
3021 Comwallis Rd., RTP, NC 27709-2889, USA

**CO-DIRECTOR:** Prof. Jurgen Engemann, University of Wuppertal, Microstructure Research  
Center, Obere Lichtenplazer 336, 5600 Wuppertal, Germany

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The Institute was divided in four sessions which included comprehensive reviews and discussions focused on four main subjects as described below:

(1) Descriptions and discussions of thin film deposition techniques (plasma and ion beam sputtering systems, systems and basic principles of chemical vapor deposition, physics and chemistry of film growth from the vapor phase, and molecular beam epitaxy systems and related technology). Descriptions on the state of the art hardware and critical analyses of the basic principles of each thin film deposition technique were presented.

(2) Critical reviews on the synthesis of multicomponent oxide thin films and processing-microstructure-property relationships were presented. Specific subjects included: (a) plasma and ion beam sputter- and laser ablation-deposition of high temperature superconducting, ferroelectric, and electro-optic thin films; (b) chemical processing science and properties of perovskite dielectric thin films; (c) laser ablation-deposition of multicomponent oxide thin film heterostructures; (d) synthesis of optical thin films with focus on fundamentals and applications. A second part of the session on multicomponent oxide thin films was focused on the discussion of compositional and microstructural characterization of the films. Specifically, ion beam-based characterization of oxide thin films was discussed, including a description of a novel pulsed ion scattering spectroscopy technique that can be used to perform *in situ*, *real-time* compositional and microstructural surface characterization during film growth at relatively high background pressures. Critical reviews were presented on electron spectroscopic analysis of multicomponent thin films with emphasis on oxides and on electron microscopy of oxide thin films with emphasis on microstructural analysis both from the experimental and computer modeling point of views.

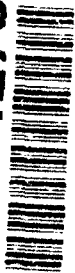
(3) The third session was dedicated to reviews and discussions of multicomponent semiconductor and metallic thin films for application in microelectronics. Specific subjects that were discussed included: (a) deposition fundamentals and properties of metallic and diffusion barrier films; (b) growth, properties, and applications of epitaxial silicides; (d) Si-based epitaxial heterostructures, with emphasis on process limitations, material characterization, and devices; (e) synthesis of compound semiconductors, including fundamental processes and device applications. This session also included discussions on ion and electron beam-based characterization of electronic materials, with specific descriptions of high sensitivity laser-induced photo-ionization spectroscopies for analysis of impurities in semiconductors at the part per trillion level.

(4) The final session was dedicated to the discussion of high temperature superconducting devices, including SQUIDS, microwave devices, Josephson junction-based devices, and infrared detectors. A discussion of ferroelectric and electro-optic thin film-based devices was also presented.

The main objective of the Institute was to bring together scientists from different fields of research such as semiconductor, oxide, and metallic materials, as well as those working on the development of systems for thin film processing and characterization. The highly interdisciplinary nature of the Institute allowed participant scientists to interchange ideas in an environment rarely available in other international conferences. This has opened a window of opportunities for collaborations in research and development, which more and more will require interdisciplinary exchange of ideas.

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## **LECTURES**

### **Plasma Sputter-Deposition Systems: Plasma Generation and Basic Physics**

Dr. S.M. Rossnagel, IBM, Yorktown Heights, USA

### **Technology and Applications of Filamentless rf Ion Sources: Ion Beam Sputtering**

Prof. J. Engemann, University of Wuppertal, Wuppertal, Germany

### **Physics and Chemistry of Film Growth from Vapor Phase**

Prof. J.E. Greene, University of Illinois, Urbana, USA

### **The Growth of Crystalline Films by Molecular Beam Deposition**

Dr. J.C. Bean, AT&T Bell Laboratories, Murray Hill, USA

### **Physical Vapor-Deposition of Multicomponent Oxide Thin Films: Techniques, Basic Deposition Processes and Film Processing-Microstructure-Property Relationships**

Dr. O. Auciello, MCNC, Center for Microelectronics, RTP, USA

### **Pulsed Laser Deposited Metal-Oxide Based Superconductor, Semiconductor, and Dielectric Hetero-structures and Superlattices**

Prof. T. Venkatesan, University of Maryland, Maryland, USA

### **Synthesis of Optical Thin Films: Fundamentals and Applications**

Prof. R.P. Howson, Loughborough University, Leicestershire, U.K.

### **Ion Beam-Based Characterization of Multicomponent Oxide Thin Films**

Dr. A.R. Krauss, Argonne National Laboratory, Argonne, USA

### **Electron Spectroscopic Analysis of Multicomponent Thin Films with Emphasis on Oxides**

Prof. T. Barr, University of Wisconsin-Milwaukee, Milwaukee, USA

### **Transmission Electron Microscopy of Oxide Films**

Dr. R. Ramesh, Bellcore, Red Bank, USA

### **Deposition Fundamentals and Properties of Metallic and Diffusion Barrier Films**

Prof. Y. Pauleau, Institute National Polytechnique, Grenoble, France

### **Growth, Properties and Applications of Epitaxial Silicides**

Dr. S. Mantl, Institut für Schicht und Ionentechnik, Forschungszentrum Jülich, Germany

### **Si-Based Epitaxial Heterostructures: Devices, Material Characteristics and Process Limitations**

Dr. D.C. Houghton, National Research Council, Ottawa, Canada

### **Synthesis of Compound Semiconductors: Fundamentals and Devices**

Dr. C. Whitehouse, Defense Research Agency, Malvern Worcs, U.K.

### **Characterization of Electronic Materials Using SNMS and SIMS**

W. Calaway, Argonne National Laboratory, Argonne, USA

### **High Temperature Superconducting Thin Film-Based Devices**

Dr. C. Heiden, Institut für Schicht und Ionentechnik Forschungszentrum Jülich, Germany

### **Ferro-electric and Electro-optic Thin Film-Based Devices**

Prof. S.B. Krupanidhi, PennState University, Pennsylvania, USA

## **CONTRIBUTED PAPERS PRESENTED**

### **SECTION 1: THIN FILM DEPOSITION TECHNIQUES**

#### **Discharge Density Increase for a High Rate Magnetron Sputtering system**

W. Posadowski (Technical Univer., Poland)

#### **Hard Tungsten-Carbon Coatings Deposited by Reactive Magnetron Sputtering**

P. Gouy-Pailler (CNET, France)

#### **Influence of Sputtering Gas Pressure and Substrate Bias on Intrinsic Stress and Crystallinity of Coatings Produced by Magnetron Sputtering**

V. Texeira (Universidade do Minho, Portugal)

#### **Sputter-Deposition of Multicomponent Films: What Parts of the Process Affects the Elemental Composition of the Films**

D. Theirich (University of Wuppertal, Germany)

#### **Ion Beam Activated Solid State Amorphization Reactions in Multilayered Structures**

L. Pranevicius (Kaunas Univer., Lithuania)

#### **YBCO Superconducting Thin Films Deposited by Ion Beam Sputtering: PO<sub>2</sub> Dependence of the Crystallization Heat Treatments**

S. Benayoun (Faculté des Sciences, Poitiers, France)

#### **Physics and Chemistry of Film Growth from Vapor Phase**

J.E. Greene (University of Illinois, USA)

#### **The Influence of Precursors on the Preparation of Thin Pyrite Films by Metal-Organic CVD**

S. Fietcher (Hahn-Meitner-Institu, Germany)

#### **Development of Surface Topography Under Intense Ion Bombardment and Its Influence on the Spatial Distribution of Sputtered Particles**

E.S. Maskhova (Moscow State Univer., Russia)

#### **Influence of Particle Energy on Intrinsic Stress in Coatings Produced by PVD Processes**

M. Andristcky (Universidade do Minho, Portugal)

#### **Molecular dynamics Study of Film Growth with energetic Ag Atoms**

C.M. Gilmore (G. Washington Univer., USA)

#### **Thickness Dependence of the Superconducting Transition Temperature of YBCO Films: Single Layer vs. Superlattice Behavior**

J. Hasen (University of California, San Diego, USA)

#### **Microstructural Evolution of Multicomponent Epitaxial Films from Chemical Precursors**

M.J. Cima (MIT, USA)

## CONTRIBUTED PAPERS PRESENTED

### SECTION 2: MULTI-COMPONENT/LAYERED OXIDE THIN FILMS

#### Chemical Processing Science and Properties of Perovskite Dielectric Thin Films for ULSI Applications

S.K. Dey (Arizona State University, USA)

#### PZT Ferro-electric Thin Films Produced by Laser Ablation-Deposition

U. Varshney (American Research Corp., USA)

#### Features of Growth and Parameters of Trilayer Systems YBCO/PZT/YBCO Prepared by Laser Ablation

Yu.A. Boikov (Ioffe Technical Institute, Russia)

#### Prospects of Transparent Conducting Oxide-Based Solar Cells-A Close Look

A. Subrahmanyam (University of Erlangen, USA)

#### Deposition of Oxide Thin Films: An Overview of Philips Research Programs

R.M. Wolf (Philips Research, The Netherlands)

#### In-Situ Compositional Analysis of Multi-element Thin Films

T. Roberts (Argonne National Laboratory, USA)

#### A Proposition for a Novel Reactive Sputter-Deposition System for Synthesizing Multicomponent Thin Films

S. Maniv (Rafael, ISRAEL)

#### Preparation and Characterization of Doped-NbO<sub>5</sub> Thick Films for Hybrid Devices

R. Ochoa (University of Louisville, USA)

#### Ferro-electric (Pb, La) (Zr, Ti)O<sub>3</sub> (PLZT) Thin films Grown by Pulsed Laser Evaporation

R.P. Riveiro (Universidade do Minho, Portugal)

#### Transverse Electro-optic Properties of Magnetron Sputtered PLZT Thin Films

F. Wang (Clemson University, USA)

#### DISCUSSION GROUP 1

Thin Film Deposition Techniques

#### DISCUSSION GROUP 2

High Temperature Superconducting Thin Films

#### DISCUSSION GROUP 3

Ferroelectric, Electro-optic and Optical Thin Films

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DISC GROUP 3

## **CONTRIBUTED PAPERS PRESENTED**

### **SECTION 3: THIN FILMS FOR MICROELECTRONIC APPLICATIONS**

#### **Laser Processing of Ti Films for Microelectronic Applications**

V. Cracium (University College London, U.K.)

#### **Study of Transport of Sputtered Species in Plasma Sputter-Deposition of Single and Multicomponent Thin Films**

J.C. Moreno Marin (Universidad de Alicante, Spain)

#### **Characterization of Epitaxial CoSi<sub>2</sub> Growth on (001)Si Using a Co/Ti Bilayer and an alloy source Material**

S. Hsia (Duke University, USA)

#### **Pulsed Excimer Laser Induced Reactions at the Tungsten-Silicon Interface**

S. Luby (Slovak Academy of Sciences, Czechoslovakia)

#### **Rapid Pulsed Laser Annealing of Silicon-Nitride/Silicon Interface States**

J. Meixner (Universität Erlangen, Germany)

#### **Stress in Si<sub>1-x</sub>Ge<sub>x</sub> Films Prepared by Ion Beam Sputtering**

F. Meyer (Universite Paris Sud, France)

#### **Band Engineering of High Bandgap Semiconductors by Superlattices**

S. Sitar (Swiss Federal Institute of Technology, Switzerland)

#### **Thin Films of Layered Semiconductors by Van der Waals Epitaxy**

W. Jaegerman (Hahn-Meitner Institut, Germany)

### **DISCUSSION GROUP 4**

Fundamentals of Deposition and Characterization of Multicomponent Thin Films

### **SECTION 4: DEVICES**

#### **Electrical and Optical Properties of HTSC Bolometers on Si**

S. Bhattacharya (University of Maryland, USA)

#### **Phase Lock-in in Series Connected Nb-Al-Nb Planar Josephson Weak Links**

K. Saitoh (Hitachi, Ltd., Japan)

### **DISCUSSION GROUP 5**

Multicomponent Thin Film-Based Devices

### **DISCUSSION GROUP 6**

Thin Films for Microcircuit Metallization

### **DISCUSSION GROUP 7**

Compound Semiconductor Thin Films

### **DISCUSSION GROUP 8**

High Temperature Superconducting, Ferroelectric, Electro-optic, and Compound Semiconductor Thin Film-Based Devices"

**Summary of the NATO/ASI and Overview of Future Directions in Research and Development of Multicomponent Thin Films**

O. Auciello

**General discussion**

Feedback from NATO/ASI participants about the school

**Concluding Remarks and Farewell**

O. Auciello and J. Engemann

**PUBLICATION**

**Multicomponent and Multilayered Thin Films for Advanced Microtechnologies: Techniques, Fundamentals, and Devices**

O. Auciello and J. Engemann (Eds.) , Kluwer Academic Publishers, The Netherlands, May 1993.